Throughput and Fairness-Aware Dynamic Network Coding in Wireless Communication Networks

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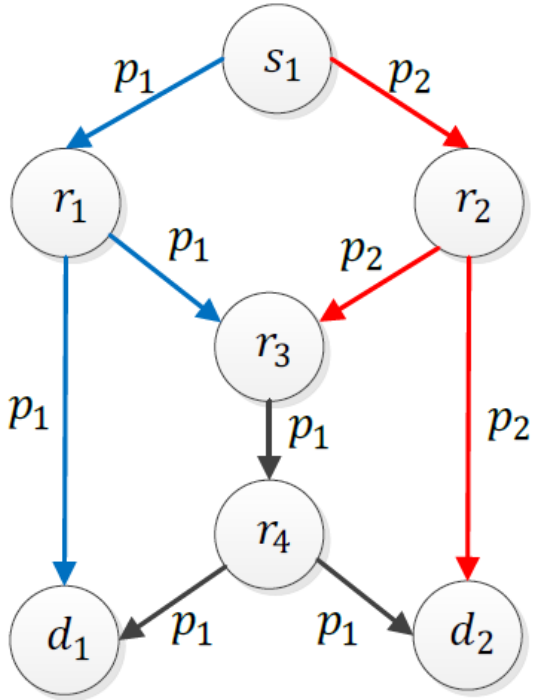
Agenda

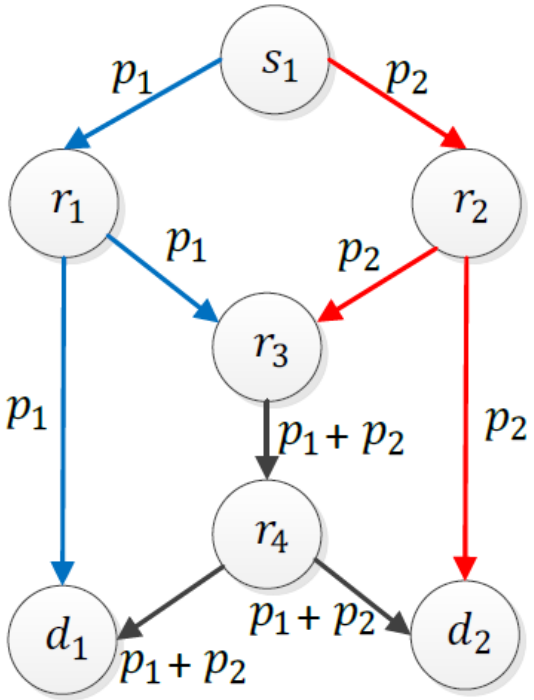
- Introduction
- Motivation and setting
- Proposed methods
  - Dynamic network coding
  - Fair dynamic network coding
- Simulation results
- Conclusion

Network Coding in Wired Networks

- Bottleneck problem



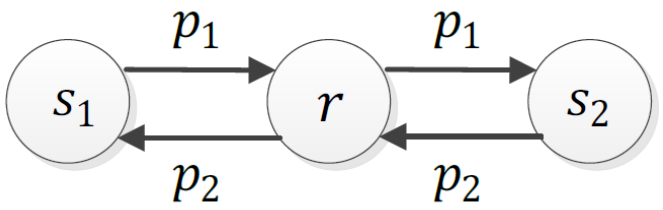
Without coding



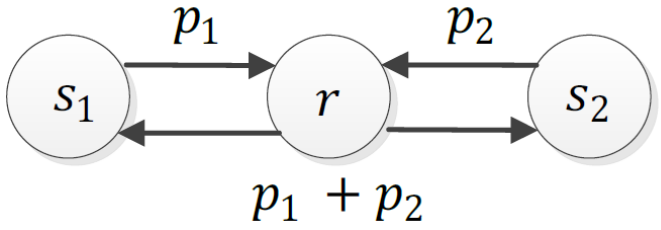
With coding

Network Coding in Wireless Networks

- No coding
  - 4 transmissions



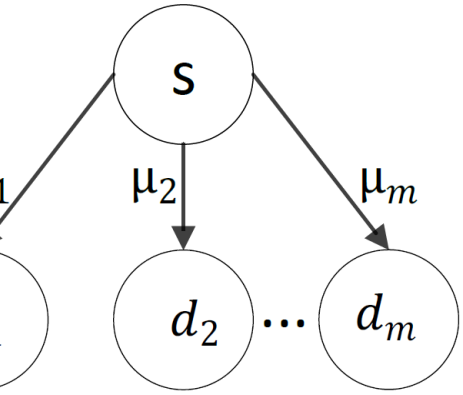
- Coding
  - 3 transmissions



- Inter-flow coding
  - Increases the throughput

Network Coding in Wireless Networks

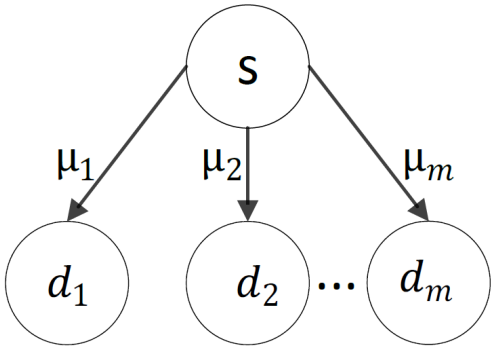
- Intra-flow coding
  - Reliability



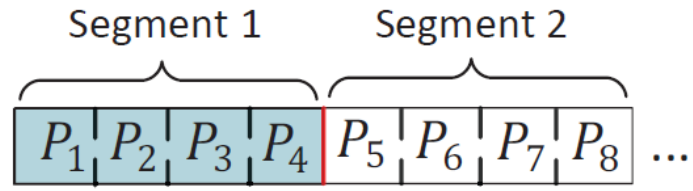
$$\sum_{i=1}^{4} \beta_i . P_i$$

Setting

- One source
  - Broadcasts a set of packets
- Multiple destinations
  - Independent erasure channels
- Equal size time slots
  - One packet transmission per time slot
- Objective
  - Throughput

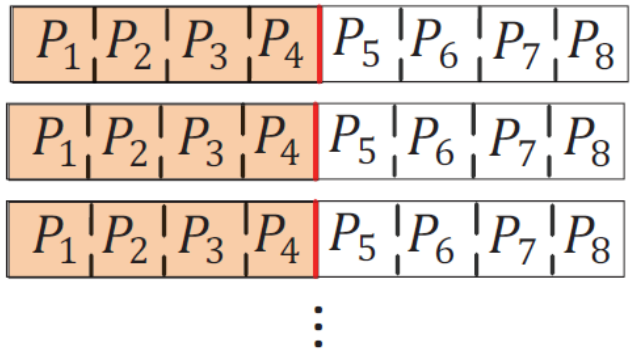


Introduction (Segment Coding)



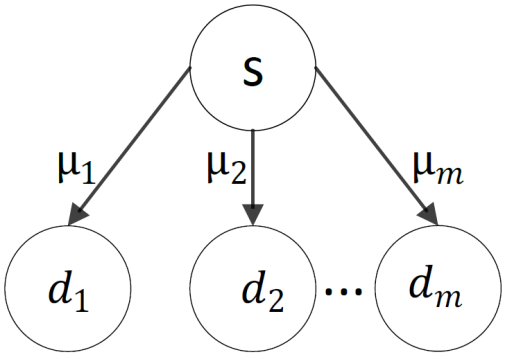
Coding

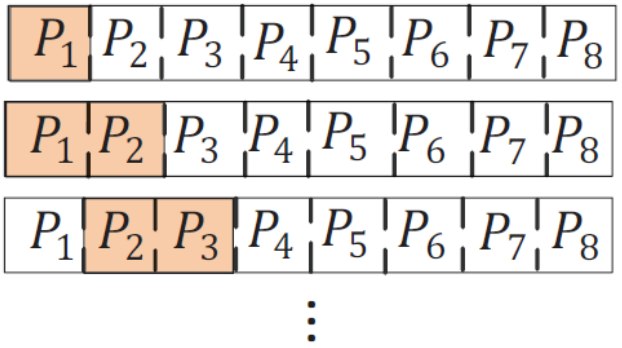
$$\sum_{i=1}^{4} \beta_i . P_i$$



Segment coding

Time





Dynamic coding

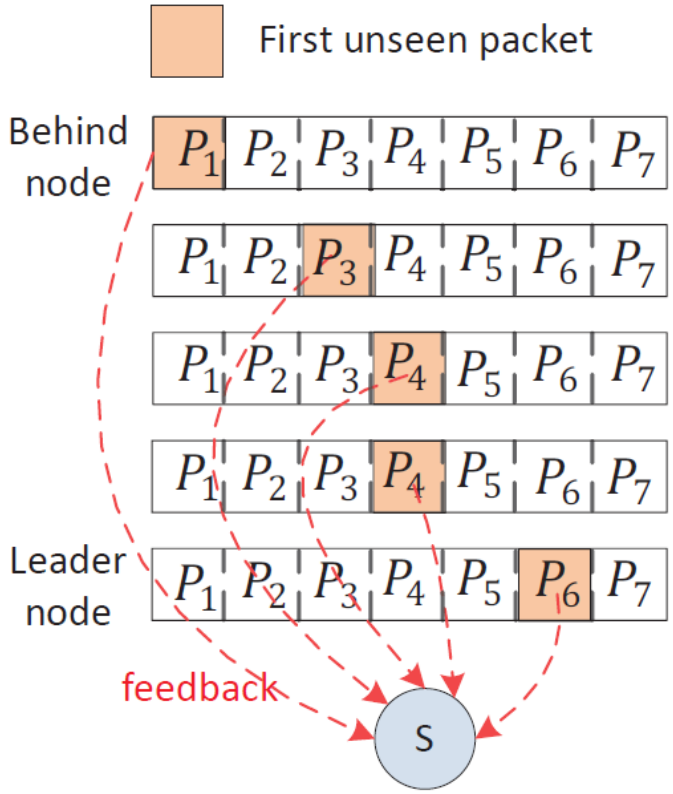
Introduction

- Seen packet (Sundararajan'08)
  - A node has seen a packet P if it can generate a linear combination of the form P + Q, using the received coded packets in its buffer
  - $\alpha_{1,1}p_1 + \alpha_{2,1}p_2 + \alpha_{3,1}p_3$
  - $\alpha_{1,1}p_1 + \alpha_{2,1}p_2 + \alpha_{3,1}p_3$

    $\alpha_{1,2}p_1 + \alpha_{2,2}p_2 + \alpha_{3,2}p_3$
  - Seen packets can be removed from the sender's buffer

Introduction

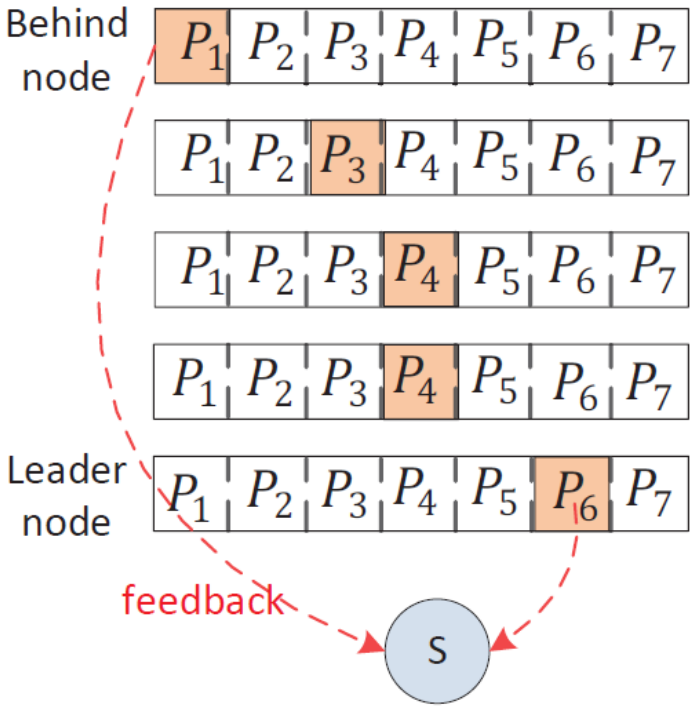
- ARQ with network coding (ANC)



Coded packet: $P_1 + P_3 + P_4 + P_6$

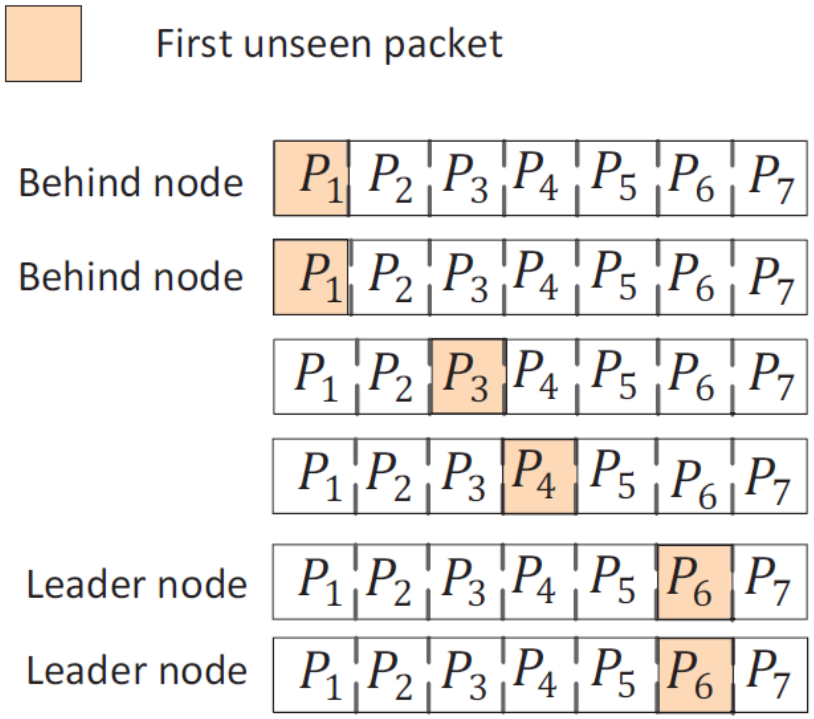
Idea

- Behind and leader nodes
- Code packets in the range of the first unseen packets by the leader and behind nodes



Coded packet: $P_1 + P_2 + P_3 + P_4 + P_5 + P_6$

Multiple Behind and Leader Nodes



- 2 methods to deal with multiple behind and leader nodes

Dynamic NC without Overhearing

- All leaders need to transmit a feedback
  - A receiver that missed the last transmission cannot be a leader node
  - If the index of the first unseen packet is equal to the largest index included in the received coded packet, then the node is a leader node
- Behind nodes
  - If all the behind nodes receive the current transmissions, they do not send any feedback messages

Dynamic NC with Overhearing

- Two feedbacks per time slot
- Just one leader and one behind node send feedback
  - Set a back-off time based on the erasure rate of the nodes
  - The receivers listen to the channel
  - Leader node finishes its back-off time
    - Send feedback if has not overheard feedback from the other leaders

Dynamic NC with Overhearing

- Two feedbacks per time slot
- Just one leader and one behind node send feedback
  - The behind nodes that have received the last transmissions do not need to transmit a feedback
  - Only one of the nodes that was a behind node in the previous slot, and missed the current transmission should send a feedback

Throughput

- In ANC each transmission has innovative information for all of the nodes
  - Achieves the maximum throughput
  - Proof
- The same approach can be used to prove that the DNC is throughput optimal

Fair Dynamic NC

- Unfairness of ANC and DNC
  - The nodes with low error rates receive more coded packets than the other nodes, and become the leaders
  - The nodes with higher error rates might not be able to decode the packet for a long time

Fair Dynamic NC

- A trade-off between fairness and throughput

$$x = (1 - w) \times L - w \times (m - L)$$

  - w : fairness factor
  - L : number of leaders
  - m : number of users

- If x>0, the sender adds a new packet to the coded packet

Simulations (Definitions)

- Decoding delay unfairness

$$f'_D(j) = \frac{\sum_{i=1}^{m} |D(i,j) - \bar{D}(j)|}{m}$$

- Decoding delay fairness

$$f_D(j) = \frac{1}{f'_D(j)}$$

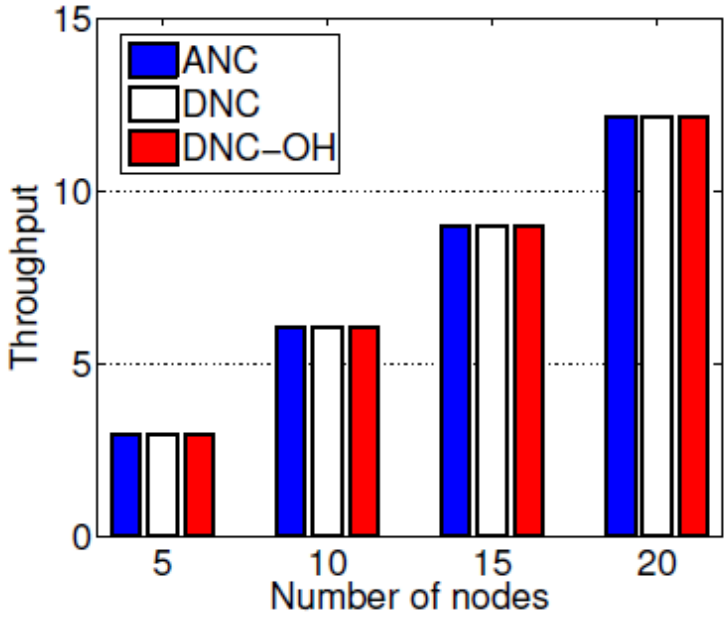
- Decoding unfairnes

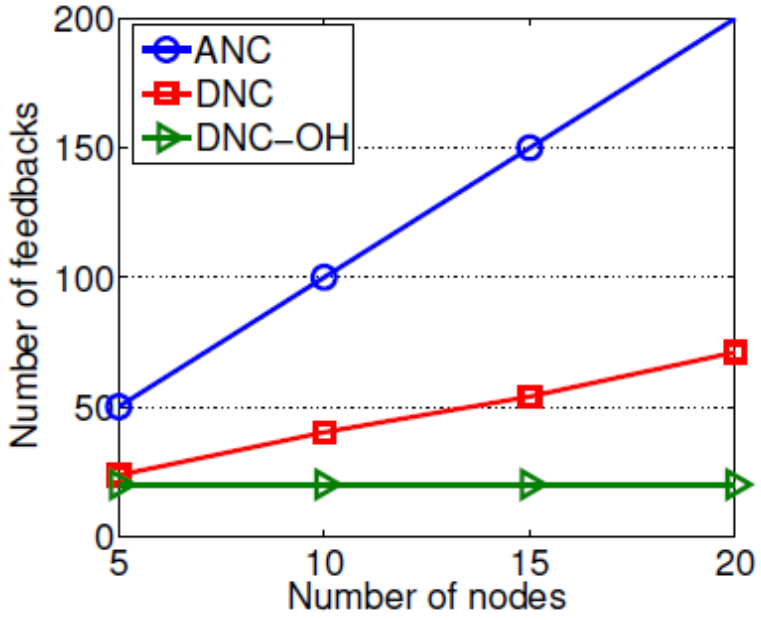
$$f'_E = \frac{\sum_{i=1}^{m} |E(i) - E|}{m}$$

Simulations

- ANC: ARQ with NC
- DNC: Dynamic network coding without overhearing
- DNC-OH: Dynamic network coding with overhearing

$$\mu \in [0.3, 0.9]$$

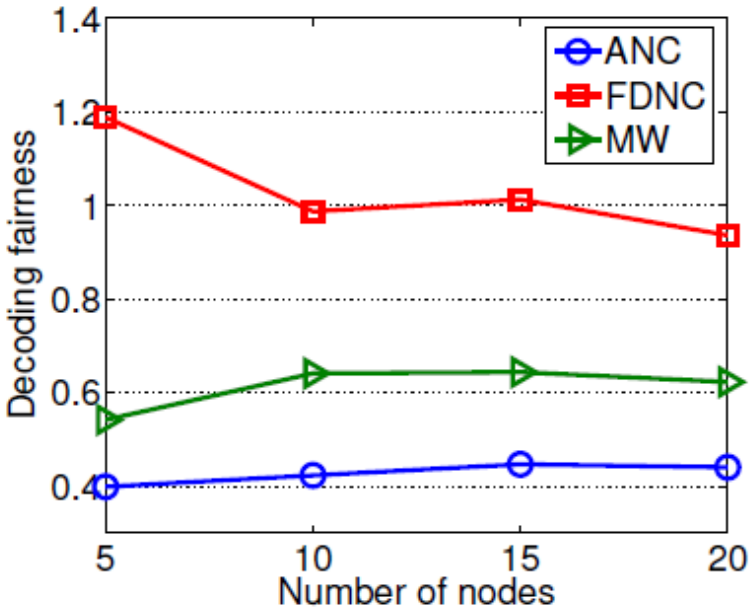




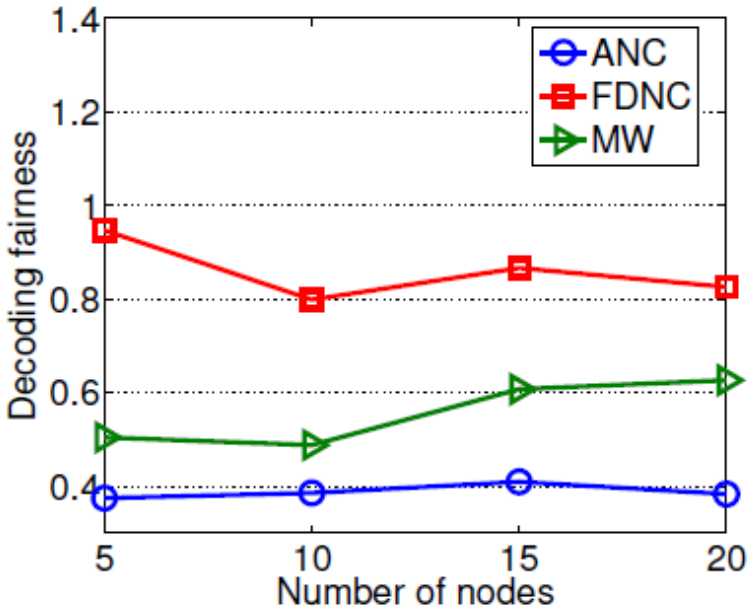
Simulations (Decoding Fairness)

- ANC: ARQ with NC
- FDNC: Fain dynamic network coding
- MW: Moving window

$w = 0.7$



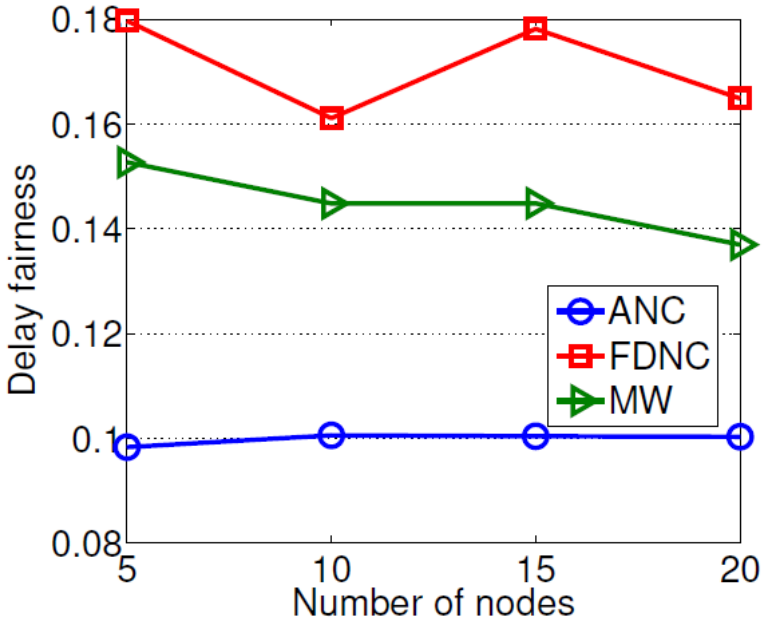
$\mu \in [0.3, 0.9]$



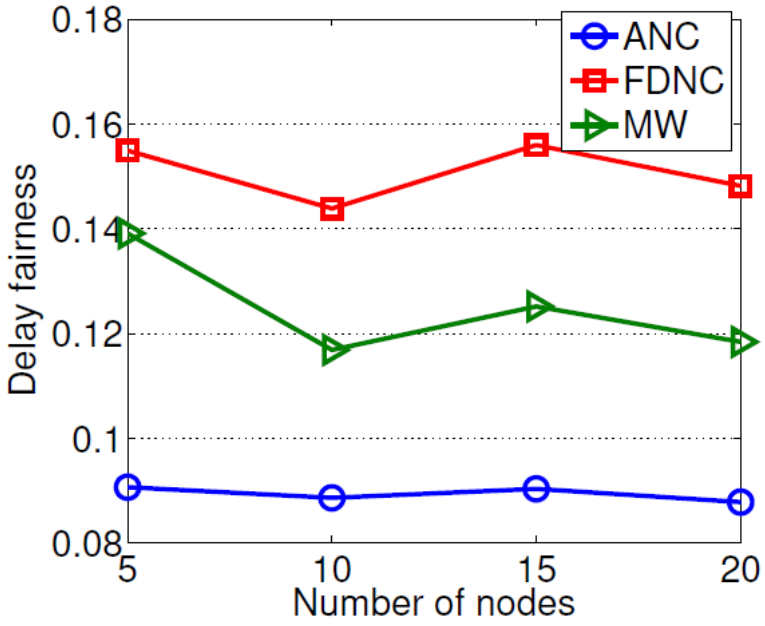
$\mu \in [0.4, 1]$

Simulations (Delay Fairness)

$w = 0.7$



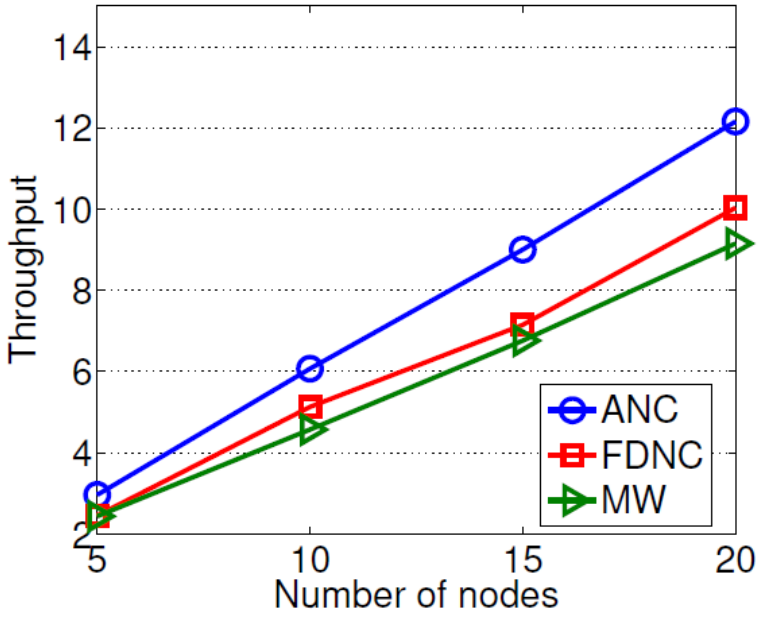
$\mu \in [0.3, 0.9]$



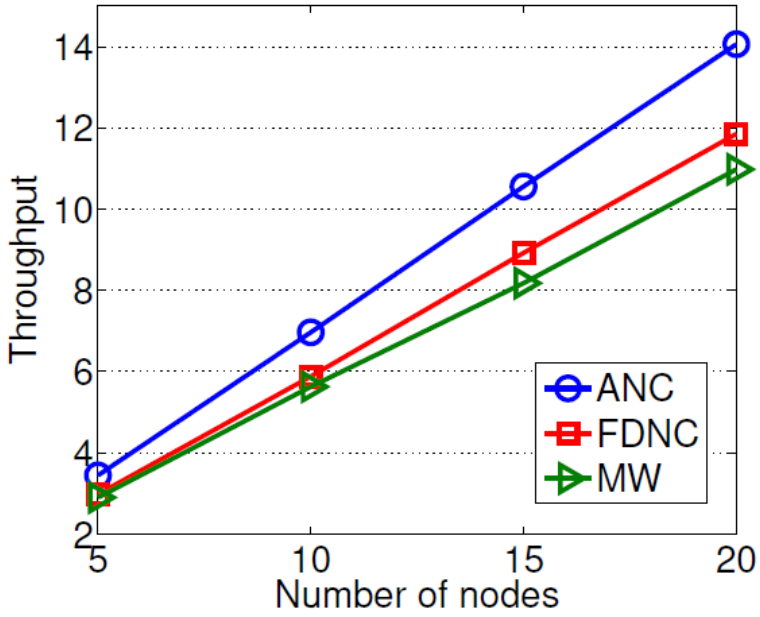
$\mu \in [0.4, 1]$

Simulations (Throughput)

$w = 0.7$



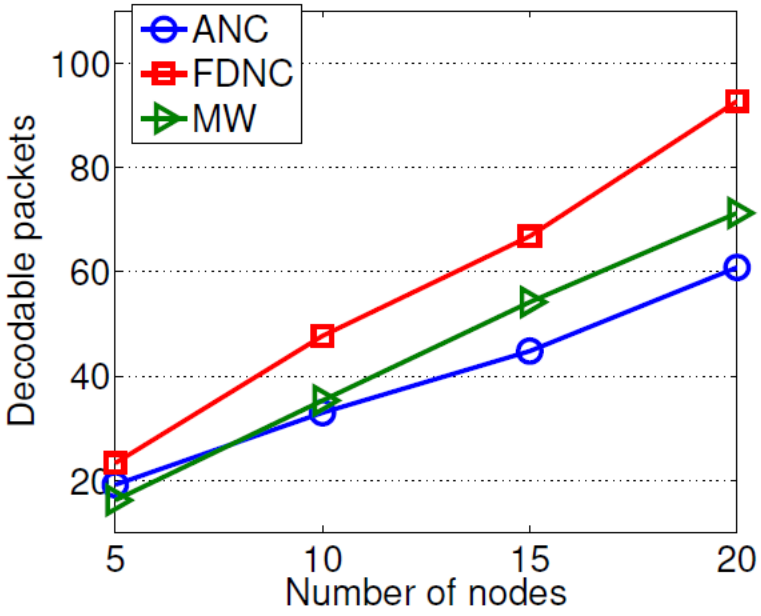
$\mu \in [0.3, 0.9]$



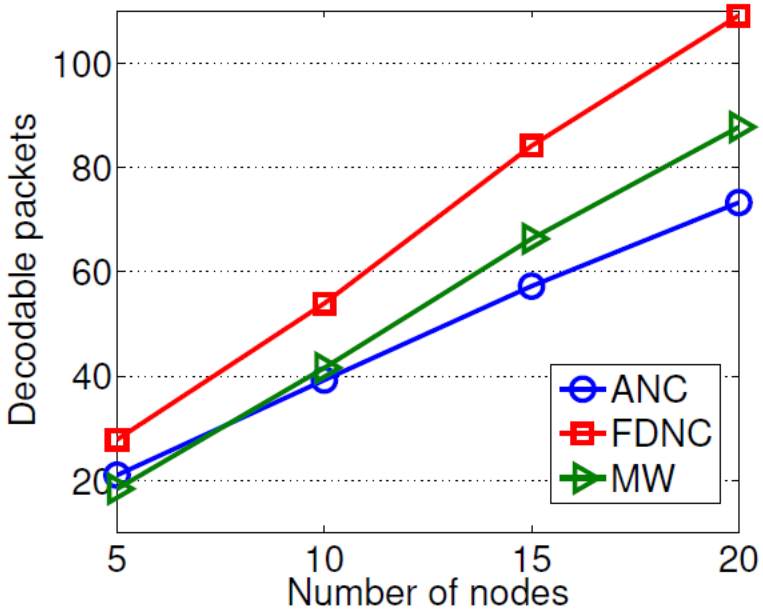
$\mu \in [0.4, 1]$

Simulations (Decodable Packets)

$w = 0.7$



$\mu \in [0.3, 0.9]$



$\mu \in [0.4, 1]$

Summary

- Dynamic coding increases the throughput of network coding
  - Too many feedback messages
- We propose the DNC and DNC-OH methods to reduce the number of feedbacks
- We propose the FDNC method to provide decoding and decoding delay fairness

Questions